Preliminary Analysis of University of North Dakota Aircraft Data from the FIRE Cirrus IFO-II

Semi-annual Status Report

for the period

April 15, 1994 to October 14, 1994

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NASA Grant NAG-1-1351

1.0 Introduction

This report describes the progress and performance by the University of North Dakota under NASA Research Award NAG-1-1351 - "Preliminary Analysis of University of North Dakota Aircraft Data from the FIRE Cirrus IFO-II," for the period April 14, 1994, to October 15, 1994. Included is a summary of the data archival status and preliminary analysis efforts.

2.0 Data Archival

The data collected by the Particle Measuring Systems (PMS) 2D-C probe carried by the UND Citation during the Cirrus IFO-II have been processed through a special algorithm supplied by the National Center for Atmospheric Research (NCAR). The purpose of the algorithm is to compute the cloud ice water content (IWC) and other microphysical parameters for times when the Citation was in cloud. It uses an automatic particle habit classification scheme and mass-dimensional relationships formulated by Dr. Andrew Heymsfield of NCAR. For classification, the scheme uses the particle area ratio, which is the ratio of detected particle area to the area of a circle with a diameter equivalent to the detected particle maximum dimension. This software is identical to the package used to compute IWC values for the NCAR Sabreliner and King Air data sets for this project.

The 2D-C data from all Citation flights, except 11/28/91 (9 of 10 flights) when the probe wasn't working, have been processed to yield 5-second averages. These data may be integrated in the vertical to derive such properties as ice water path through the cloud. These data files will be forwarded to the Langley DAAC for inclusion in the FIRE archive and will be accompanied by appropriate documentation for their use. This represents the final data product to be added to the FIRE archive; all other Citation products have already been submitted.

3.0 Data Analysis

Two analysis tasks were pursued during this reporting period. The first involved revisions to a manuscript being submitted to the Journal of the Atmospheric Sciences for the special FIRE issue. The paper is entitled "Satellite Remote Sensing of Multiple Cloud Layers" and is co-authored by B. Baum, T. Uttal, M. Poellot, T.P. Ackerman, J.M. Alvarez, J. Intrieri, D. O'C Starr, J. Titlow, V. Tovinkere, and E. Clothiaux. UND Citation data were used to help verify the satellite retrieval technique developed to identify cloud top heights when multiple

cloud layers are present. The revisions were made in response to reviewer comments.

The second task involved a preliminary examination of Citation cloud microphysical data under conditions when it appeared that only small ice crystals were present. There were several instances noted during the Cirrus IFO when the PMS FSSP probe seemed to be detecting ice particles but nothing was observed on the 2D-C. The nominal size range of the FSSP was 3-47 um and the 2D-C was 33-1056 um. These probes operate on different principles - the FSSP uses Mie scattering theory to size and count particles based on the forward scattering of light, while the 2D-C detects particles through the shadowing of light illuminating an optical array.

Since Mie theory applies to spherical particles, the use of the FSSP for measurements where non-spherical ice crystals are present is problematic. The typical response of the FSSP in mixed phase clouds is to produce a flattening of the size spectrum, which for liquid water studies is considered a contamination of the data that leads to erroneously high computed values of liquid water content (Gardiner and Hallett, 1985; Heymsfield and Miloshevich, 1989). The primary problem is that complex scattering and reflection increases the effective sample area of the probe to some unknown value. Gardiner and Hallett concluded that this occurs because particles that would normally be outside the depth of field can provide a strong enough signal to be accepted, or larger ice crystals may be counted even though their centers are outside the sample volume. They noted that these effects plus the possibility of splintering and impaction on the optics can result in errors in particle concentrations as great as 2-3 orders of magnitude.

It is significant to point out that most uses of the FSSP to date have been for measurements of spherical liquid particles and aerosols where the signal from ice has been treated as noise It would appear that in a cloud that is all ice, particularly if the particles are small and quasi-spherical, quantitative information could be gleaned from the FSSP data. In their parameterization of cirrus particle size spectra, Heymsfield and Platt (1984) considered the FSSP data in the 10-20 um size range to be valid, based on comparison with a 1D-C probe.

Additional evidence for the utility of the data can be seen in spectra derived from a preliminary analysis of the Citation FIRE data. Figure 1 shows an average FSSP spectrum from a period when the aircraft was sampling near the top of a cirrus layer at an altitude of 12.4 km and temperature of -63.5 C. During this time, the 2D-C was not sensing any particles. Notice that the spectrum has a sharp peak at approximately 20 um and is not flattened as reported in the studies mentioned previously. Total number concentrations were running on the order of 100-600 l-1.

During FIRE, the Citation also carried a continuous formvar replicator operated by the Desert Research Institute. This instrument is capable of capturing particles as small as 7 um in the form of replicas which can be counted, sized and analyzed for crystal habit. A preliminary analysis of the replicator data during the time of the FSSP measurements indicates particle sizes of <50 um (most much smaller than 50 um) and concentrations of 100-400 l-1 (Arnott, personal communication). This corroborates the FSSP observations and shows that with further analysis it may be possible to quantify these and other such cirrus measurements.

References

Gardiner, B. and J. Hallett, 1985: Degradation of in-cloud Forward Scattering Spectrometer Probe measurements in the presence of ice particles. J. Atmos. Oceanic Technol., 2, 171-180.

Heymsfield, A. and L. Miloshevich, 1989: Evaluation of liquid water measuring instruments in cold clouds sampled during FIRE. J. Atmos. Oceanic Technol., 6, 378-388.

Heymsfield, A. and C.M.R. Platt, 1984: A parameterization of the particle size spectrum of ice clouds in terms of the ambient temperature and the ice water content. J. Atmos. Sci., 41, 846-855.

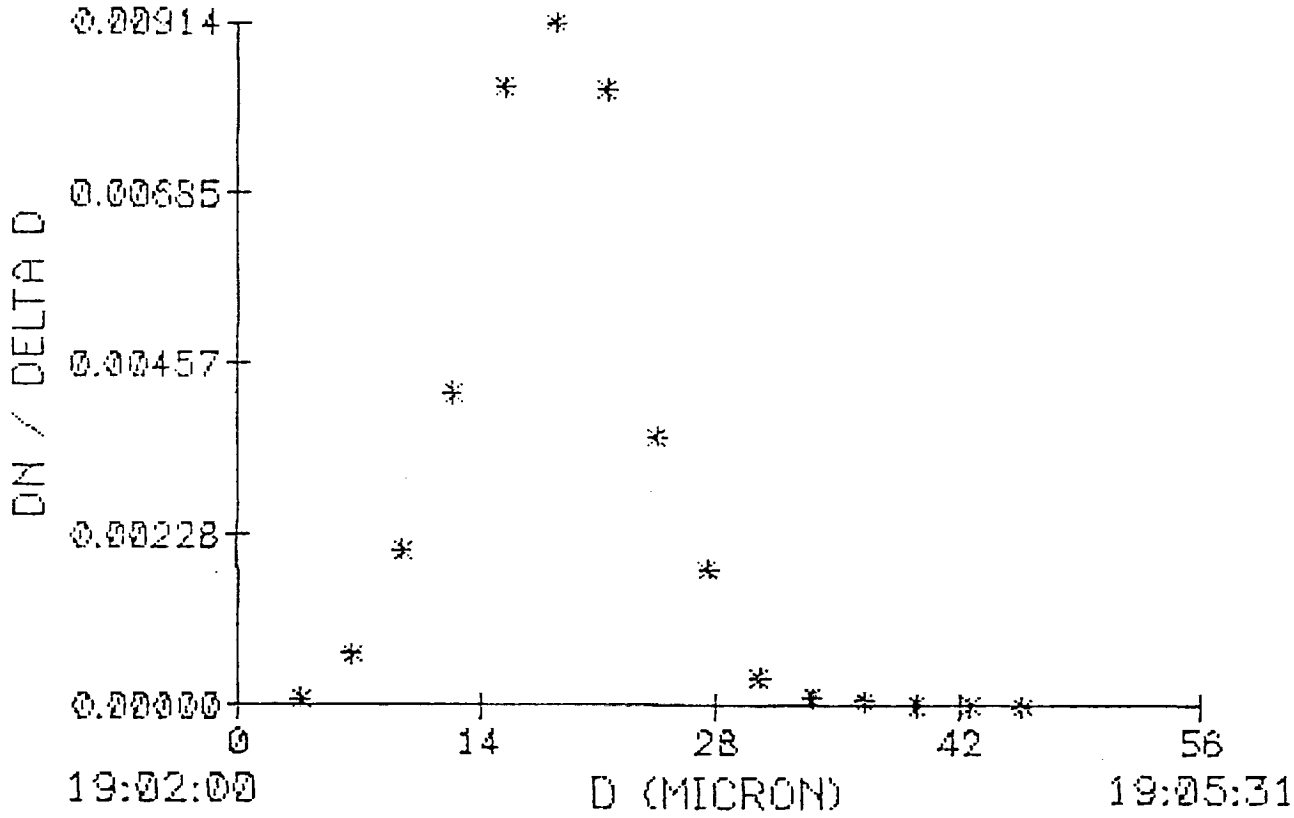

Figure 1. Average FSSP spectrum from a portion of the 5 December 1991 mission